

## MODULE FOR ADAPTIVE TEACHING PLANNING FOR A TUTORING SYSTEM

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### Abstract

The teaching process has been strengthened by the emergence of modern computer technologies, which have permitted developing distance education mainly through the use of the Internet. In this field tutoring systems have become one the most benefited and important tools for teaching. However, adapting tutoring systems to students' capacity is one the issues that has just begun being explored [1, 2]. This paper describes a module for adaptive teaching planning for a tutoring system that is under development [3, 4]. This module modifies the teaching contents depending on the estimation of two of students' cognitive abilities: memorization and comprehension.

**Keywords:** Adaptive Teaching Planning, Tutoring System, and Cognitive Abilities.

### Abstract

La enseñanza ha sido fortalecida con la aparición de las modernas tecnologías computacionales, que han permitido desarrollar la educación a distancia principalmente con el uso de la Internet, siendo los sistemas tutores una de las herramienta más beneficiadas e importantes para esté fin. Sin embargo, la adaptación de los sistemas tutores a las capacidades de los estudiantes es un punto que a penas está siendo explorado [1, 2], es por ello que dada la experiencia en el CENIDET para desarrollar sistemas tutores [3, 4] se implementó un módulo de planificación adaptativa que modifica el contenido de enseñanza dependiendo de la cuantificación de la calidad de las habilidades cognoscitivas de memorización y comprensión del estudiante.

**Palabras claves:** Planificación Adaptativa de Enseñanza, Sistema Tutor, y Habilidades Cognitivas.

# 1 INTRODUCTION

The teaching process requires a constant improvement in the existing methods, tools and systems for this purpose, mainly concerning distance education. This is not entirely new: distance education based on traditional means has a long history. The novelty consists of requiring that teaching be assisted by modern computer techniques, multimedia and communications for offering technologically advanced environments that permit to carry out teaching attractively and efficiently.

One of the modern technologies is the world communications network, Internet, which has had and will continue to have a large impact on different activities and areas of human development. There will be no human activity, which, one way or another, will not be affected by this new revolution that has expanded the limits of all the disciplines. This includes distance teaching, specially tutoring systems, whose range of action is almost limitless; i.e., they have the ability to reach any place in the world that is connected to the Internet.

Thus, the proliferation of Web sites that offer tutoring systems on different fields of knowledge constitutes a clear example. Such tutoring systems extend from those that are just simple digital books to the most sophisticated, which use artificial intelligence techniques that offer advanced interaction means with the student.

# 2 TUTORING SYSTEMS

There exist many definitions and terms for referring to tutoring systems. In the Military Handbook 284 part 3 and in the Military Standard 1379D, the term used for denoting these systems is interactive courseware, which is defined as follows [5]: “Computer program for controlling the student’s instruction, which determines the time and order of teaching. The student progresses through the sequence of events making decisions and choices. The instruction proceeds according to the student’s responses.”

The objective of tutoring systems is reproducing the teacher’s activities in the teaching-learning process, both individually and collectively. Though, the first tutoring system of this type was developed over 30 years ago, researchers have not devised a system that satisfies all the requirements achieved by a human teacher.

## 2.1 Architecture of a Tutoring System

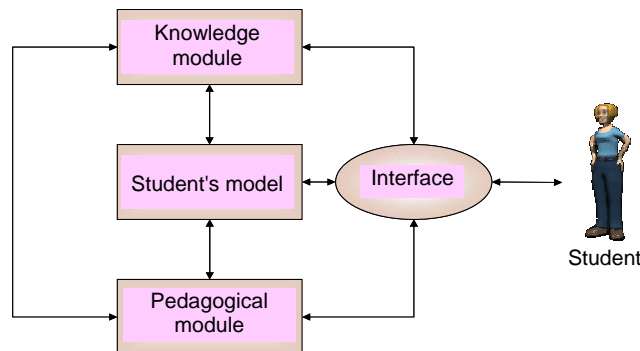


Figure 1: Natural division of an ITS.

A traditional way of representing tutoring systems consists of dividing its components in a natural way (Figure 1) [6, 7]:

- a) Knowledge module.
- b) Student's model.
- c) Pedagogical module.
- d) Interface.

The **knowledge module** stores the knowledge representation of the subject to be taught. It consists of the following basic elements: a knowledge base and an inference engine. The main methods for representing knowledge are: semantic networks or directed graphs, production systems or rules, agents, and case based reasoning.

The **student model** is a representation of the knowledge acquired by the student, as well as other characteristics among which the most relevant are cognitive abilities, attentiveness, dedication, number of reviews, etc. raditionally the techniques used for designing this model are overlay and buggy.

The **pedagogical module** can normally apply one or more teaching techniques and has the capacity of dividing the teaching plan into sub-goals for directing a student in a customized way. Additionally, it can dose up the contents according to the records of the general strategic decisions and the results of the student's historical behavior. The main didactical methods that have been used are passive student and participative student.

Finally, the **interface** processes the in and out communication flow. This is not an easy task in this kind of systems, since the communication channel between the student and the system is very narrow.

### 3 COGNITIVE ABILITIES

The word cognition refers to the abilities of the logical and rational thought of individuals [8]. Such abilities are responsible for facilitating the adequate integration of the individual with the surrounding environment. Each ability is constituted by cognitive abilities such as: memorization, comprehension, reasoning, analysis, etc.

In 1956 Benjamin Bloom leaded a group of educational psychologists that developed one of the most important classifications of intellectual behavior. This originated a taxonomy that includes three domains: cognitive, psychomotor and affective [9].

The cognitive domain (which is relevant for this investigation), is constituted by six levels (Figure 2) and is highly important, since it offers a starting point for the basic classification of the cognitive abilities required from the individuals for achieving the learning of knowledge.

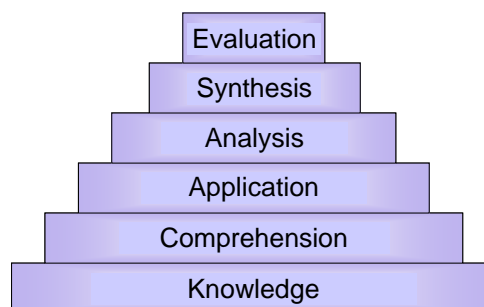


Figure 2: Organization of the cognitive domain levels.

**Knowledge** is defined as the act of remembering previously learned material. It presupposes remembering a rich gamut of materials that ranges from concrete facts to theories; but what is needed altogether is remembering the appropriate information.

**Comprehension** is defined as the capacity for acquiring the meaning of the material. It can be revealed when translating the material from one form to another (words to formulas), when interpreting the material (explaining it or summarizing it), and when estimating which will be the future trends (prediction of consequences or effects).

**Application** refers to the capacity of using the learned material in new and concrete situations. It can include the application of elements such as: rules, methods, concepts, principles, laws, and theories.

**Analysis** refers to the capacity of subdividing the material to be learned into its constituting parts, such that its organization structure can be understood. It includes the identification of the parts, the analysis of the relationships among parts, and the realization of the involved organization principles.

**Synthesis** implies joining parts, such that a whole is integrated, which may require the production of a unique communication (theme or discourse), an operation plan (investigation proposals), or a set of abstract relationships (plan for information classification).

Finally, **evaluation** consists of the capacity of judging the value of some material based on personal values and/or opinions, which results in a final product, with some given purpose, without real correct or incorrect answers.

## **4 MODULE FOR ADAPTIVE TEACHING PLANNING**

The module for adaptive teaching planning is basically implemented above the pedagogical module according to the typical architecture of tutoring systems. The adaptive planning operates on the contents to be taught by the system and considers the memorization and comprehension cognitive abilities of the student. The specific consideration of the memorization and comprehension abilities is highly important in the students' learning process, since these are the first steps in the process (according to Bloom's taxonomy) through which higher levels of knowledge assimilation and processing are achieved.

For achieving adaptive teaching planning considering the aforementioned cognitive abilities, it is necessary to relate the knowledge about the course contents with the memorization and comprehension abilities required for the understanding of the material by the student.

### **4.1 Basic Functions of the Module**

The adaptive planning module performs the following basic functions:

- a) Measuring the student's memorization and comprehension abilities, in such a way that the student is not intimidated by this assessment.
- b) Planning the contents of the topic to teach according to the assessment of the memorization ability.
- c) Planning the contents of the topic to teach according to the evaluation of the comprehension ability.

- d) Determining if low values of the estimated cognitive abilities are due to insufficient time devoted by the student to examine the material.

## 4.2 Database Schema of the Tutoring System

All the modules of the tutoring system are supported by a database constituted by 21 tables grouped into four classes (Figure 3):

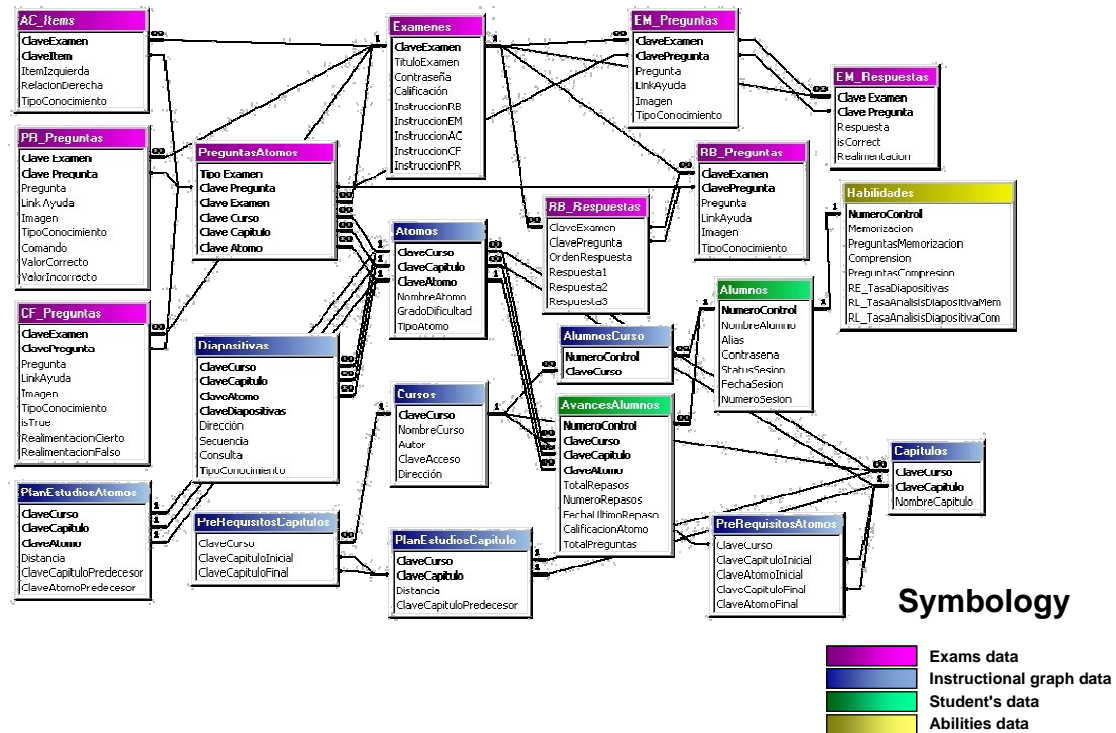


Figure 3: Database schema of the tutoring system.

- Information of the course exams, which consider five different evaluation mechanisms.
- General information on students (identification data).
- Information on assessment of the students' cognitive abilities (memorization and comprehension).
- Information of the student's model (representation of the students' learning degree).

## 4.3 General Architecture of the Tutoring System

The tutoring system used in this investigation is being developed at the *Centro Nacional de Investigación y Desarrollo Tecnológico* [3, 4]. The tutoring system modules have been adapted for the adequate operation of the adaptive teaching module, which has resulted in the current system architecture, shown in Figure 4.

As can be seen in Figure 4, the four modules in the lower part of the figure constitute the tutoring system proper; while the four upper modules are authoring tools for facilitating the creation of courses in different fields of knowledge.

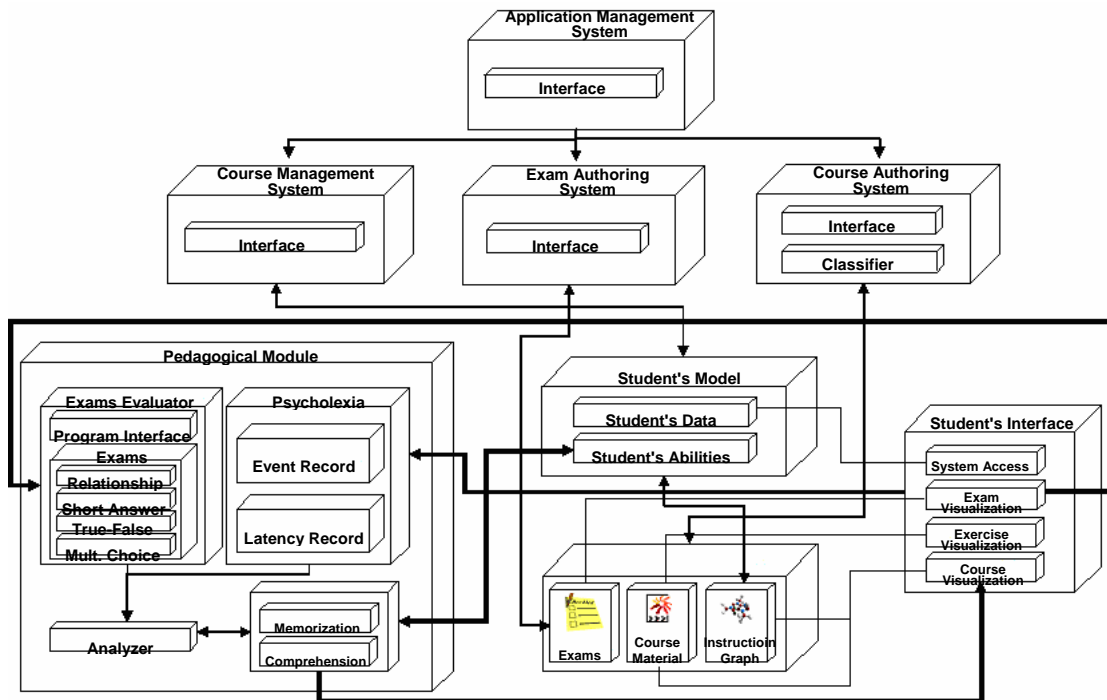


Figure 4. General architecture of the tutoring system.

#### 4.4 Architecture of the Adaptive Planning Module

This investigation focuses on the adaptive planning module, which constitutes a part of the pedagogical module. The pedagogical module is comprised by four sub-modules: exams evaluator, psycholexia, analyzer, and planner. The first two collect information about the student; while the third analyzes this information and instructs the planner on the actions to be taken. The architecture of the pedagogical module is shown in Figure 5.

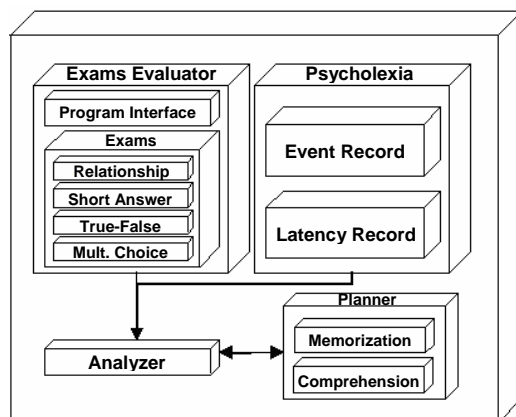


Figure 5: Pedagogical module architecture.

The exams evaluator sub-module is responsible for evaluating the student's learning degree of the tutoring system material, using five different types of assessment mechanisms: short answer exam, true-false answer exam, relationship exam, multiple choice exam, and external application exam.

The psycholexia sub-module is in charge of measuring the memorization and comprehension abilities and other elements of the students. The name of the module follows from one of the psychology areas, which studies the intellectual abilities of individuals concerning their quality.

One of this discipline techniques (observation) was chosen in order to assess the students' cognitive abilities without intimidating them. Every observation is reported using records; one of which is *events*, used by the system for measuring the memorization and comprehension abilities. *Latency* is another type of record that the system uses for determining if the time devoted to study the material is a relevant factor in case the student shows a deficiency in his cognitive abilities, and other factors that will be described later on.

Finally, the planner module carries out the needed adaptations of the course contents, as well as reminding the student about needed review of some materials in order to make the learning process easier: all of this according to the instructions of the analyzer module. The planner sub-module has two mechanisms for adaptive planning of the contents: *memorization planning* and *comprehension planning*. Memorization planning in turn is constituted by two phases that remind and show the student the contents that he needs to review before studying a specific topic. Comprehension planning is more complex than the first one, and through this planning the system determines the number of slides that it will show to the student when studying each topic.

#### **4.5 Assessment of the Cognitive Abilities**

Since one of the important aspects of the tutoring system is to avoid intimidating the student when assessing his memorization and comprehension abilities, an extensive search of psychological techniques and methods was conducted to this end. The search revealed that there exists a technique in psycholexia called *observation*, which permits measuring the individuals' intellectual abilities without being aware that they are being evaluated. Observation is the most frequently used psychological technique and its fundamental value consists of being able to study individuals in a natural way; i.e., the observer gets in direct contact with the individual's behavior. Every observation uses different tools for recording the specific activities investigated. The instruments used by the tutoring system are *event recording* and *latency recording*.

Event recording consists of counting individual's behaviors as they occur. Recording the number of times that a behavior under investigation occurs is an observation recording technique frequently used. In our case the tutoring system uses such recording for counting the following values: number of memorization related questions and correct answers, number of comprehension related questions and correct answers, and ratio of slides studied.

Latency recording consists of measuring the time elapsed from the beginning of a stimulus (a command) to the beginning of a behavior. Latency recording is used when the main interest is in the amount of time between an opportunity to trigger a behavior and the beginning of the behavior execution. In our case the tutoring system uses this recording for obtaining the following values: rate of study of memorization related slides and rate of study of comprehension related slides. The values for the number of memorization related questions and correct answers, and the number of comprehension related questions and correct answers are obtained from the student's answers to the exams questions; while the rate of studied slides is obtained counting the number of slides examined in each student's session.

Finally, the rates of study of memorization and comprehension related slides are obtained calculating the time elapsed from the time the system displays a slide until the student requests an action, such as viewing the next or the previous slide. These variables are used by the tutoring system for determining if the student has been devoting enough time for studying the slides materials; and if the system detects cognitive abilities deficiencies, the system will recommend the student to devote more time for studying the slides.

#### **4.6 Process of Adaptive Teaching Planning**

Once the student's memorization and comprehension abilities have been assessed, the system has the required information for carrying out the adaptive planning of the material to be taught. As mentioned in Section 4.4, the planning is divided into two parts: memorization planning and comprehension planning.

The memorization planning permits the tutoring system to recommend the student reviewing a topic that the system considers has been forgotten and is necessary for the next topic. This planning consists of two phases. The first phase is carried out when the student accesses the course chapters and triggers the following sequence:

1. Get the student's memorization value (MemStu):

$$\text{MemStu} = \frac{\text{NumMemRite} \times 100}{\text{NumMemQstn}}$$

2. Get the average memorization value for all the students enrolled in the course (AvgMem).

3. **If** (MemStu < AvgMem) **then**:

- 3.1. Get the rate of analysis of memorization related slides for the student (RAMSStu).

- 3.2. Get the average rate of analysis of memorization related slides for all the students enrolled in the course (AvgRAMS).

- 3.3. **If** (RAMSStu < AvgRAMS) **then**:

- 3.3.1. Display the message "SUGGESTION: study carefully the course material for improving learning."

- 3.4. **End if**.

- 3.5. Get the list of all the topics examined by the student such that number of reviews < recommended number of reviews (TopExaStud).

- 3.6. Filter TopExaStud eliminating the topics that the student has reviewed in the preceding six days.

- 3.7. **If** (TopExaStud.length > 1) **then**:

- 3.7.1. Display the topics in the TopExaStud list.

- 3.8. **End if**.

4. **End if**.

An illustration of the process is shown in Figure 6.

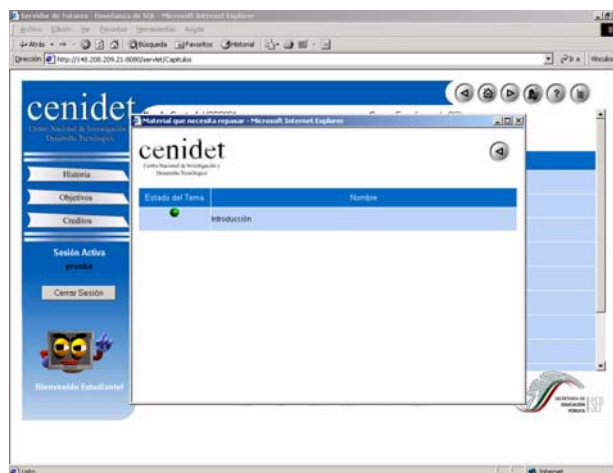


Figure 6: Illustration of the first phase of memorization planning.

The second phase of the memorization planning is carried out when the student starts to examine a topic. In this case the planner performs the following sequence:

1. Get the student's memorization value (MemStu):

$$\text{MemStu} = \frac{\text{NumMemRite} \times 100}{\text{NumMemQstn}}$$

2. Get the average memorization value of all the students enrolled in the course (AvgMem).

3. **If** (MemStu < AvgMem) **then**:



- 3.1. Get the rate of analysis of memorization related slides for the student (RAMSStu).
- 3.2. Get the rate of analysis of memorization related slides for all the students (AvgRAMS).
- 3.3. **If** (RAMSStu < AvgRAMS) **then**:
  - 3.3.1. Display the message "SUGGESTION: study carefully the course material for improving learning."
- 3.4. **End if**.
- 3.5. **If** there exists a prerequisite topic, which has memorization related slides and has been studied more that seven days ago, **then**:
  - 3.5.1. Get the slides of the prerequisite topic (PreTopSlid) and display them.
- 3.6. **End if**.
4. **End if**.

An illustration of this process is shown in Figure 7.



Figure 7: Illustration of the second phase of memorization planning.

Comprehension planning, unlike memorization planning, is applied to all students with more or less extent, except when the value of the student's comprehension ability equals the highest value (100 points) or when the student has exceeded the average number of slides that he examines in each session. Comprehension planning consists of adjusting the number of comprehension related slides (specifically explanation slides) that the system will present to the student; to this end the planner uses the following formula:

$$ES = \frac{(Com_{Max} - Com_{Stu}) \times \left( \left( \frac{DD_{Topic} \times \left( \frac{NS}{2} \right)}{DD_{Max}} \right) + \left( \frac{NS}{2} \right) \right)}{(Com_{Max} - Com_{Min})}$$

Where:

- ES = Number of explanation slides to be displayed.
- Com<sub>Max</sub> = Highest possible comprehension value.
- Com<sub>Stu</sub> = Value of the student's comprehension.
- Com<sub>Min</sub> = Lowest possible comprehension value.
- DD<sub>Topic</sub> = Difficulty degree of the topic.
- DD<sub>Max</sub> = Highest possible difficulty degree of any topic (5 points).
- NS = Number of explanation slides available for the topic.

This formula consists of two parts or filters that determine the number of explanation slides to be displayed to the student: the first filter (innermost part of the numerator) calculates the advisable number of slides according to the difficulty degree of the topic; while the second filter (outermost part) calculates the final number of slides to be displayed to the student according to the value of his comprehension ability and the value yielded by the first filter.

The comprehension planner carries out the following sequence:

1. Get the number of slides examined by the student (SlidExaStu).
2. Get the average number of slides that the student examines in each session (AvgSlid).
3. **If** (SlidExaStu < AvgSlid) **then**:
  - 3.1. Get the student's comprehension value (ComStu)
 
$$\text{ComStu} = \frac{\text{NumComRite} \times 100}{\text{NumComQstn}}$$
  - 3.2. Get the difficulty degree of the topic the student is about to examine (DD).
  - 3.3. Get the number of existing explanation slides for the topic the student is about to examine (NS).
  - 3.4. Calculate the advisable number of explanation slides to display to the student:
 
$$\text{ES} = \frac{\left( (100 - \text{ComStu}) \times \left( \left( \frac{\text{DD} \times (\text{NS}/2)}{5} \right) + (\text{NS}/2) \right) \right)}{(100 - 0)}$$
  - 3.5. Display compulsory slides and DA explanation slides.
4. **End if**.

The following example explains this process. Consider a topic whose difficulty degree equals 2 and has two compulsory and seven explanation slides. If a student had a comprehension value equal to 100, the planner would not display explanation slides, as shown in Figure 8.

Clave_A	Clave_M	Período	Calif
a1	m1	sep-dic/03	B5
a1	m2	ene-abr/04	B0
a2	m1	ene-abr/04	B0
a2	m3	may-ago/04	B4
a3	m4	sep-dic/04	B6
a4	m2	may-ago/04	B0
a5	m2	ene-abr/05	B3
a6	m4	may-ago/04	B9

Figure 8. Illustration of planning for inactive comprehension (two slides will be displayed).

If a student had a comprehension value equal to 50, the planner would yield the following value:

$$\text{DA} = \frac{\left( (100 - 50) \times \left( \left( \frac{2 \times (7/2)}{5} \right) + (7/2) \right) \right)}{(100 - 0)} = 3$$

(Note: all division results were rounded up to the closest integer.)

With this result the comprehension planner displays five slides (the two compulsory ones and three additional explanation slides), which the systems deems necessary according to the comprehension ability of the student and the difficulty degree of the topic that the student is about to examine. The result of the comprehension planning for this case is shown in Figure 9.

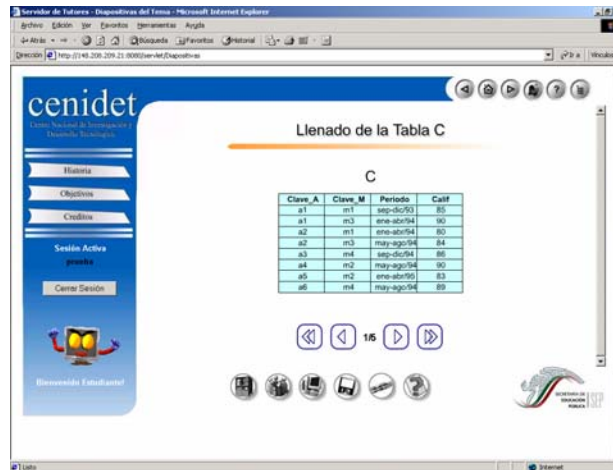


Figure 9. Illustration of planning for active comprehension (5 slides will be displayed).

## 5 EXPERIMENTAL TESTS



Figure 10. Interfaces of the tutoring systems.

In order to evaluate the benefit attained by incorporating into a tutoring system an adaptive planning that considers cognitive abilities, we used the PEMGU (Pedagogical Evaluation Methods Guidelines for Multimedia Applications). This test was developed by the European Union so that education institutions had a tool for evaluating the quality of education software [10].

The PEMGU test evaluates three main aspects:

- Technical and instructional adaptation.** This aspect evaluates the interface design, simplicity of information access and control, simplicity of usage, and documentation.
- Didactics or curricula adaptation.** This aspect evaluates curricula objectives handling, learning activities and materials, evaluation mechanisms for students, motivation factors, and application areas of the system.
- Global evaluation.** This aspect considers general features of the system when used by students.

Figure 10 shows the interfaces of the tutoring systems evaluated in the PEMGU test: on the left, the tutoring system without planning module [4]; and on the right, the tutoring system with the module for adaptive teaching planning.

The results of the tests are shown in Table 1.

Table 1. Results of the PEMGU test

No.	Element	Evaluation		
		System with planner	System without planner	Maximal value
Technical and instructional adaptation				
1	Window design	40	29	40
2	Information access & control	23	19	50
3	Use	15	10	15
4	Documentation	10	6	20
Didactics or curricula adaptation				
5	Learning objectives	9	0	60
6	Learning contents	72	65	75
7	<b>Learning activities</b>	<b>43</b>	<b>28</b>	<b>60</b>
8	<b>Evaluation</b>	<b>40</b>	<b>24</b>	<b>55</b>
9	Motivation	33	20	35
10	Program ease	19	14	30
Global evaluation				
11	Global evaluation	39	25	40
<b>TOTAL</b>		<b>343</b>	<b>240</b>	<b>480</b>

As can be observed, the results show a slight improvement in the technical and instructional adaptation due to interface changes in order to make it friendlier. Regarding didactics or curricular adaptation, the test reveals significant improvements concerning the learning activities, which shows the success of the module for adaptive learning planning. This is so because adapting the course contents to the student's memorization and comprehension abilities permits to improve the learning process. Additionally, the evaluation mechanisms showed improvement, since the new version of the system includes more and better tools for evaluating knowledge acquisition by students.

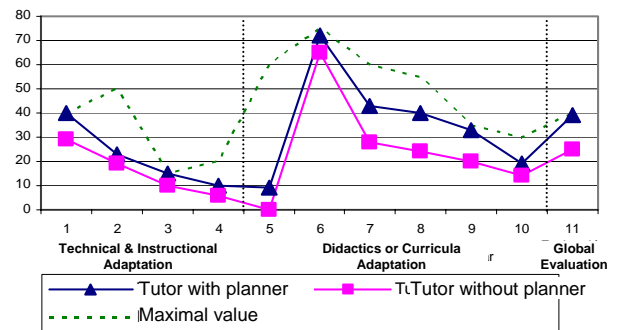


Figure 11. Graphical results of the PEMGU test.

Figure 11 shows the results of the PEMGU test graphically in order to highlight the most different aspects of both tutoring systems. The figure also includes the maximal values for each aspect of the PEMGU test.

## 6 CONCLUSIONS

Considering the cognitive abilities in the implementation of tutoring systems is not new, and some examples are the works by Julita Vassileva, Peter Brusilovsky and John Anderson [1, 11]. However, this project, unlike some of the aforementioned, includes the evaluation and involvement of students' cognitive abilities. Additionally, the adaptive planning module can support multiple courses and its operation is completely independent of the topic to be taught, which facilitates the authoring of quality tutoring systems.

Another important improvement consists of, not only considering the memorization and comprehension abilities in the planning of the material to be taught, but determining a possible cause for deficiency in one of the cognitive abilities such as the time devoted to study; thus allowing to improve the student's learning degree through suggestions.

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